EECE 522 Project Suggestions

You are free to select any relevant topic you wish but you should get it approved by me before you start working on it. You may work singly or in pairs.

Below are some suggestions – if you want to do one of these all you have to do is send me e-mail saying which one you are doing.

Each project will consist of:
- a CRLB analysis if appropriate
- “development” of a suitable estimator for the problem
- performance analysis of the estimator (including comparison to CRLB)
  - trade-off analyses if the project is a “Method 1 vs. Method 2” project
  - “impact” analysis if the project is an “Effect of…” project.
  - Theoretical Analysis
  - Monte Carlo Simulation Results

General Estimation Problems
1. Sensitivity of the General Linear Model to Assumptions
   - The general linear model assumes Gaussian noise… how sensitive is the performance of the optimal estimator to deviations from Gaussian
   - The optimal estimator for the general linear model assumes that the covariance is known. In practice we often assume that the noise is white. How sensitive is the performance of the optimal estimator to deviations from whiteness.
2. Using Sequential LS to Track a Time-Varying-Frequency Sinusoid
   - Assume you receive a sinusoid with a time-varying frequency in the presence of additive white Gaussian noise
   - Use sequential LS to track the time-varying frequency
   - How fast can the frequency change and still be tracked? What impacts that answer?
   - Suppose that the frequency change follows a simple linear function… derive the CRLB for that case and compare to the performance achieved using the Seq. LS
3. Impact on the General Linear Model of an Ill-Conditioned Observation Matrix
   - An ill-conditioned $H$ matrix is one that is close to being not-full rank
   - Such an $H$ can lead to numerical issues that can be somewhat relieved through use of singular value decomposition. Explore this issue.

Multiple-Platform Emitter Location Methods
(Recall that location processing consists of two stages of estimation: (i) estimate some signal parameters and then (ii) use those estimates to estimate the location. For these projects there is no need to perform the “first stage” of estimation… you can just generate the true signal parameters and then add noise to them to create the first stage estimates. You will, however, need to understand what is a reasonable level of noise to add)
1. **TDOA/FDOA vs. AOA Location vs. TDOA/AOA**
   - When using multiple platforms to locate an emitter it is possible to use angle-of-arrival measured at each platform to locate the emitter, it is also possible to use the TDOA/FDOA method, or one could use TDOA/AOA
   - Under what conditions does one work better than the other?

2. **Sensor Subset Selection for TDOA/FDOA**
   - Suppose you have $N$ sensor platforms but wish to use no more than $M < N$ sensors to perform the TDOA/FDOA-based location.
   - How should one select the $M$ sensors to maximize performance.

3. **Effect of Navigation Errors on TDOA/FDOA Location**
   - The standard theory assumes that the platform positions/velocities are known perfectly. If that is not true (due to the fact that you must use an on-board navigation system to determine the platform positions/velocities) then what is the impact of errors in the navigation system estimates of platform positions/velocities?

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**Single-Platform Emitter Location Methods**

(Recall that location processing consists of two stages of estimation: (i) estimate some signal parameters and then (ii) use those estimates to estimate the location. For these projects there is no need to perform the “first stage” of estimation… you can just generate the true signal parameters and then add noise to them to create the first stage estimates. You will, however, need to understand what is a reasonable level of noise to add)

1. **Doppler Location vs. Angle-of-Arrival Location**
   - It is possible to locate a radar from a single platform by observing the effect of motion on the received frequency (we talked about this in class). Alternatively, one could measure the Angle-of-Arrival of the signal and use those to estimate the location of the emitter.
   - Under what conditions does one work better than the other?

2. **Effect of Aperture Errors on Doppler Location**
   - It is possible to locate a radar from a single platform by observing the effect of motion on the received frequency (we talked about this in class).
   - The standard theory assumes that the platform positions/velocities are known perfectly. If that is not true (due to the fact that you must use an on-board navigation system to determine the platform positions/velocities) then what is the impact of errors in the navigation system estimates of platform positions/velocities?

3. **Synergy Between Doppler and Angle-of-Arrival Location**
   - It is possible to locate a radar from a single platform by observing the effect of motion on the received frequency (we talked about this in class). Alternatively, one could measure the angle-of-arrival of the signal and use those to estimate the location of the emitter.
   - When you have both Doppler and AOA measurements available how much better can you do than when you have only one or the other?
TDOA/FDOA Estimation
1. Effect of vibration on Frequency Estimation Accuracy
   - We talked in class about how to estimate frequency of a sinusoid in the presence of additive Gaussian noise.
   - However, in practice there is an additional error due to the fact that the antenna is vibrating. What is the impact of this kind of error on the performance of frequency estimation?
2. Effect of signal BW on TDOA accuracy
   - We saw equations in class that showed how BW impact TDOA accuracy.
   - Explore the practical ramifications of these equations:
     - What effect does filtering (lowpass, highpass, bandpass) the signal have on TDOA? After filtering you can decimate the signal and that reduces the amount of data that needs to be transmitted between receivers… characterize the trade-off between the data volume and the TDOA accuracy.
     - If there is a narrow-band interference in the signal you could filter it out using a bandstop filter… obviously there is a trade-off here: filtering out the interferer should help but you are also throwing away signal power so that should hurt… is there an interference power level below which the filtering is more hurtful than helpful?
3. Effect of Intermittent Signal on TDOA/FDOA accuracy
   - The theory of TDOA/FDOA estimation generally assume that the signal is continuously available during the collection time.
   - What happens if the signal is not available for part of the time?
   - If you could control when the loss occurs when would be the best time to drop data?

Radar Estimation
1. Effect of Signal Choice on Radar Accuracy
   - The choice of radar signal impacts the achievable accuracy.
   - Explore the practical ramifications of this choice.
2. Effect of Array Uncertainty on Angle-of-Arrival Accuracy
   - One of the things a radar does is measures the angle-of-arrival of the received signal by using an antenna array. The theory assumes that the positions of the antennas in the array are known perfectly
   - What is the effect of uncertainties in the array element positions?
3. Effect of Phase Error on Range/Velocities Error
   - The accuracy of a radar’s estimates is usually determined for the case of additive Gaussian noise.
   - However, in practice there is noise added directly to the phase of the received signal (one place this comes from is vibration of the crystal in the oscillator of the receiver). What is the impact of this kind of noise on the radar’s estimation performance?